



Armed Forces College of Medicine AFCM



**Heat production
regulation
&
Mechanism of fever
By
Mona Gamal El-Din Al
Anan**

INTENDED LEARNING OBJECTIVES (ILO)



By the end of this lecture the student will be able to:

1. Describe the mechanisms by which heat is produced in and lost from the body
2. List the body temperature that is recorded from rectum, oral cavity, and skin
3. Explain the mechanisms by which the body temperature is regulated
4. Explain the pathophysiology of fever



a- The Core (contents of the skull, thorax & abdomen)

b- The shell (includes the skin, subcutaneous tissues & the limbs)

Core temp. is relatively constant

Shell temp. is variable according to the

Normal Body Temp.



The normal body temperature is different from individual to individual, the average in young adult:

Orally: $36.3^{\circ}\text{C} : 37.1^{\circ}\text{C}$ “ $97.3-98.8^{\circ}\text{F}$ ” (affected by: Food ingestion, gum chewing, and mouth breathing)

Rectally: $\approx 0.5^{\circ}\text{C}$ more than oral temp.

N.B.:

The rectal temperature is representative of the temperature at the core of the body and varies least with changes in environmental temperature

Variation in body temp.



1- Diurnal rhythm : circadian fluctuation

(It is lowest in the early morning & rises to maximum in the early evening due to change in MR)

2- Sever exercise □ During exercise, the heat

produced by muscular contraction

accumulates in the body and the rectal

temperature normally rises as high as 40 °C

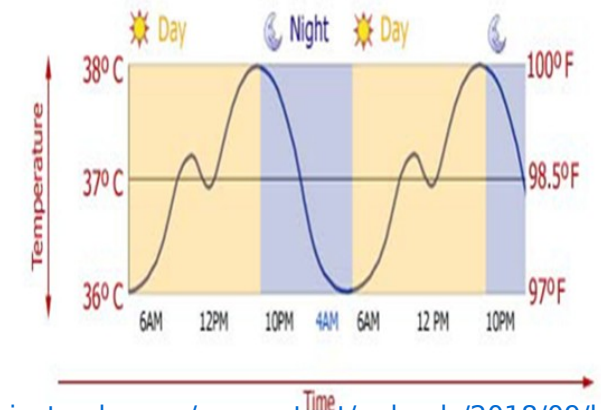
(104 °F), due in part to the inability of the heat-dissipating mechanisms to handle the greatly increased

amount of heat produced.

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Circadian Rhythm (Body-Temperature Cycle)



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Variation in body temp.



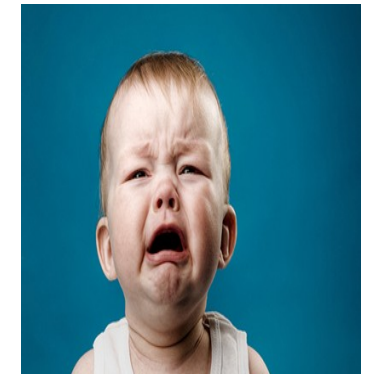
3 - Sex: In females the body temp. rises by 0.5 in the second half of menstrual period “due to thermogenic effect of progesterone”



4 - Emotions: increase body temp. “due to sympathetic activity & unconscious tensing of the muscles”



5- Age: Temperature regulation is less precise in young children and they may normally have a temperature that is 0.5 ° or so above the established norm for adults



Variation in body temp

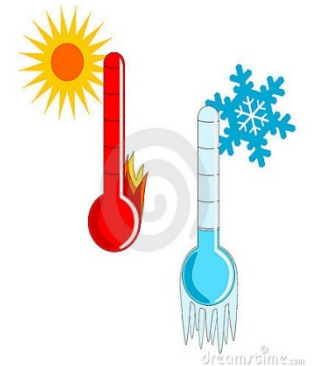


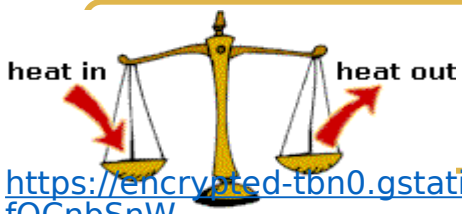
6 - Individual variation: Some persons have temp. higher than the normal range (constitutional hyperthermia)

7 - Endocrine factor: It is chronically elevated $\approx 0.5^{\circ}\text{C}$ when the metabolic rate is increased, e.g. hyperthyroidism, and lowered when the metabolic rate is low, as in hypothyroidism



8 - Environmental temp.: Body temp. increases in hot weather and decreases in cold





Heat Balance



$$\text{Heat gain} = \text{Heat loss}$$

WHY ???? Because the balance between heat production and heat loss determines the body temperature, that must be relatively constant for normal body functions

WHY ??? Because the temperature alters the speed of chemical reactions since the body's enzyme systems have optimum temperature for function

SO, a group of reflex responses that are primarily integrated in the hypothalamus, operate to maintain body temperature within a narrow range in spite of wide fluctuations in environmental temperature

Heat Balance



The main factors that lead to **heat production (gain)** are:

1- Muscular exercise

2- All the vital processes that contribute to the basal metabolic rate

3 - Endocrine factors like:-

* Thyroxin (slow prolonged effect)

* Epinephrine and norepinephrine (rapid and short effect).

4- External environment : sun rays ↑ temp. leads to increase of chemical activity of all cells)

5- Food intake: Assimilation of food (SDA thermal effect of food)

6- Brown fat: Special type of fat only in infants with high rate of metabolism and richly supplied by sympathetic nervous system

Ways of heat loss



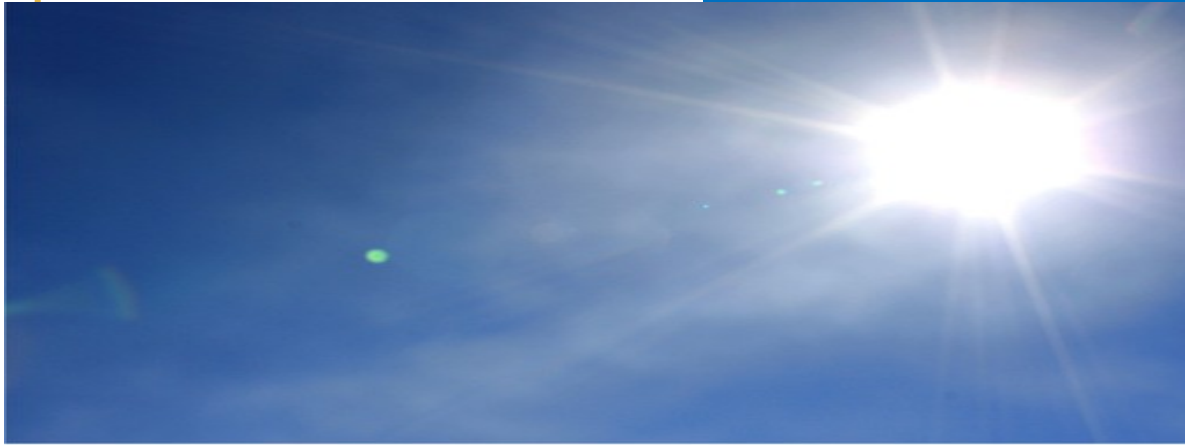
- ❖1- Conduction
- ❖2- Convection
- ❖3- Radiation
- ❖4- Evaporation

The heat is lost from the body by:

Radiation, conduction, and vaporization of water in the respiratory passages and on the skin. Small amounts of heat are also removed in the urine and feces



Ways of heat loss



(a) Radiation



(b) Evaporation



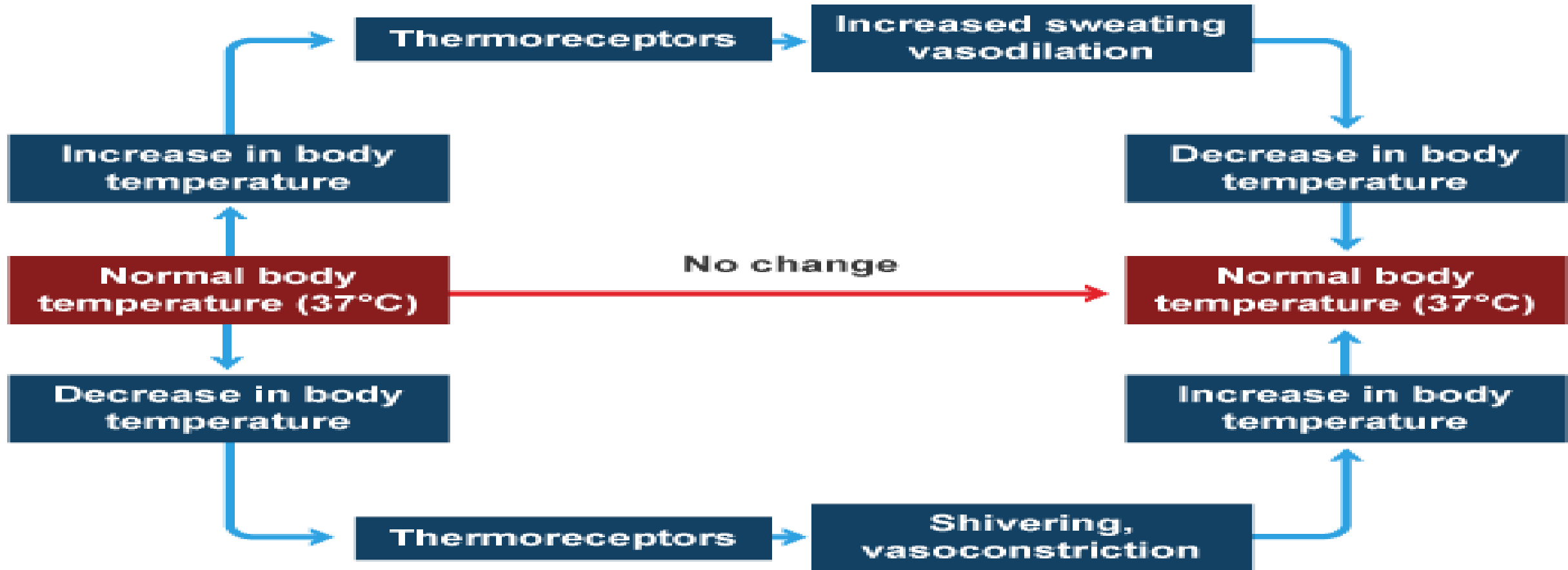
(c) Convection



(d) Conduction

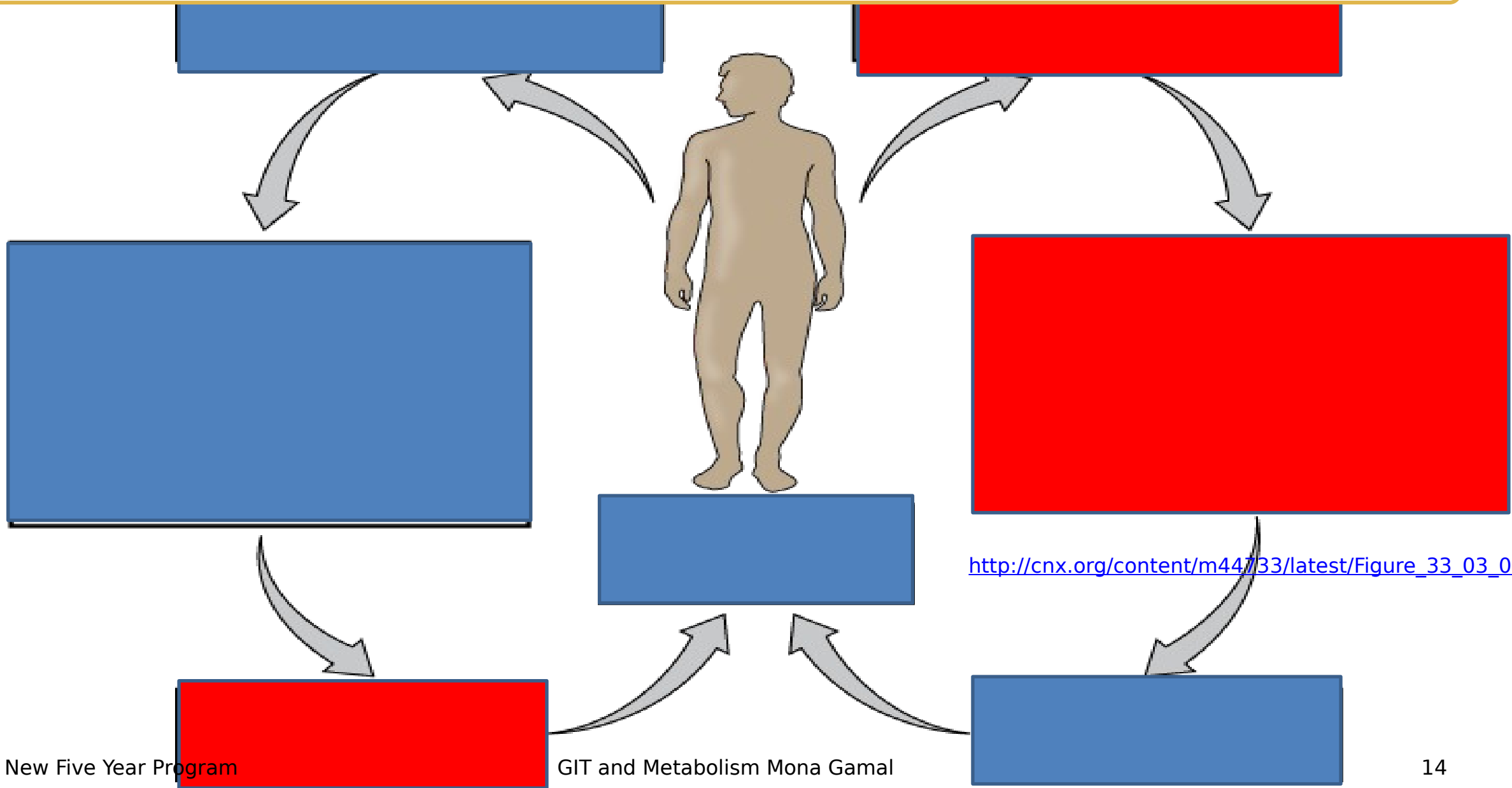
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Body temp. regulation



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Body temp. regulation

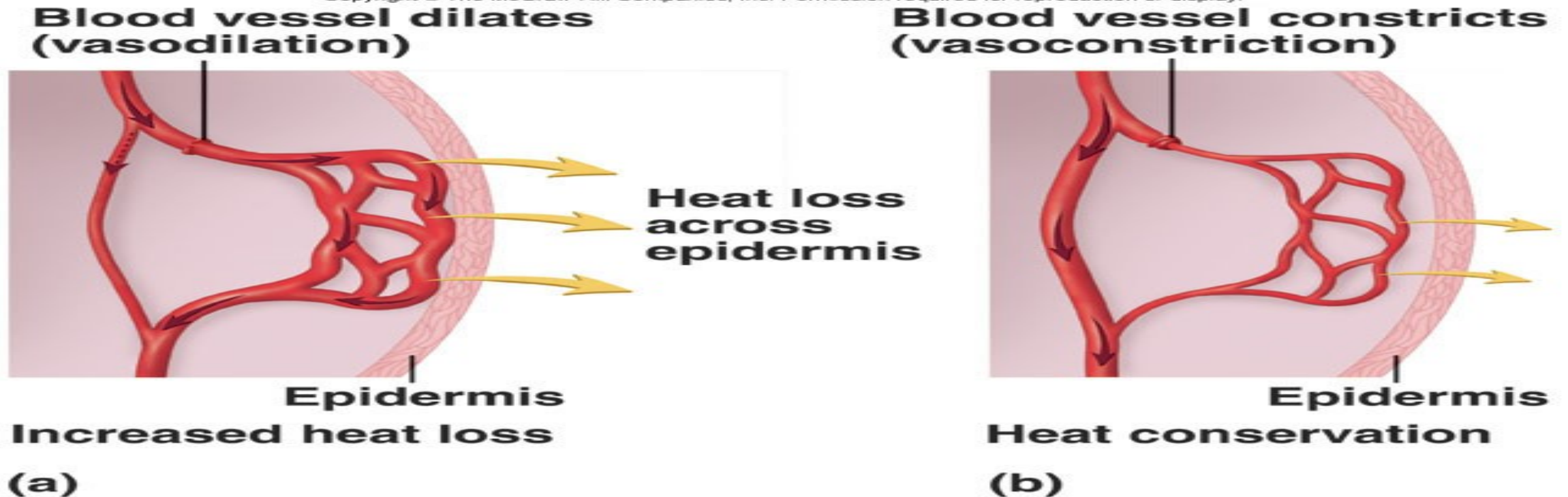


Heat Loss



- ❖ Most of heat production in the body is liberated in the deep organs then lostthe skin & then to air via blood

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Evaporation



Water evaporation from body occurs in two forms

Energy varies from 30 to over 900 kcal/h

Insensible perspiration

From the skin and lungs ≈ 50 mL/h in humans

Sweating

- ❖ From sweat glands
- ❖ Regulated by SNS
- ❖ Humidity $1/\alpha$ the sweat evaporation

Panting in animals have no sweat glands

Vaporization of 1 g of water removes about 0.6 kcal of heat

Heat loss



N.B.: Conduction is greater in presence of air currents and greatest in the presence of water

N.B.: If the temperature of air adjacent to the skin rises and becomes equal to skin temperature it forms an insulator zone preventing further heat loss

Heat loss



Environmental temp. must be less than body to have heat loss by radiation

The greater the thermal gradient the more will be the amount of radiation

In comfortable zone (24: 34°C) temperature, 70% of heat loss “radiation, conduction, convection”

and 30 % “evaporation”

If the surrounding temp. is greater than that of the skin, “sweating” only mechanism for heat loss

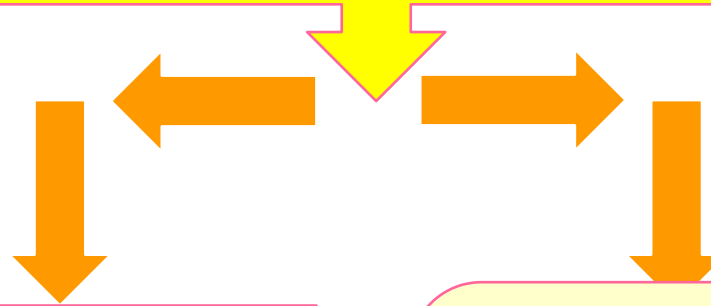
At 21 °C, “vaporization” is a minor component in humans at rest

As the environmental temperature approaches body temperature, radiation losses *decline* and vaporization losses *increase*

Sweat secretion



Mechanism of sweat secretion



Primary secretion

From the deep subdermal secretory portion of the sweat gland, similar to plasma without plasma proteins (water, Na^+ , Cl^- , K^+ , urea, lactic acid)

Secondary secretion

By the duct, modified primary secretion mainly by reabsorption of Na^+ and H_2O . Its concentration depends on the rate of sweating

Mechanism of secretion

Types of sweat glands

Acclimatization of sweat secretion

Effect of aldosterone hormone

On exposure to cold, decreasing heat loss is by.....

- 1) Cutaneous vasoconstriction.
- 2) Cutaneous vasodilation.
- 3) decreasing muscle activity.
- 4) decreasing appetite.

Heat-loss mechanisms do not include.....

- 1) reducing activity
- 2) the evaporation of sweat
- 3) behavior measures such as wearing light, loose clothing
- 4) vasoconstriction of peripheral blood vessels
- 5) vasodilation of peripheral blood vessels

Heat-loss mechanisms do not include.....

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- 3) behavior measures such as wearing light, loose clothing
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- 5) vasodilation of peripheral blood vessels

Temperature regulating centers = hypothalamic thermostat



- ❖ The hypothalamus integrates body temperature information from sensory receptors from the following five inputs
 - ❖ each contributes about 20% of the information that is integrated

The skin

Deep tissues

Spinal cord

Extra hypothalamic portions of the brain

The hypothalamus itself

Temperature regulating centers = hypothalamic thermostat



Heat loss center
Site: Anterior hypothalamus

Heat gain center
Site: Posterior hypothalamus

They detect variation of body temperature from the set point
They discharge impulses to the effector organs to modify rate of heat production or loss

Set point

It is a standard critical temperature, when body core temperature either increases or decreases above or below it, several thermoregulatory mechanisms takes place to bring it back to this temperature

Threshold core temperatures for each of the main temperature-regulating responses When reached the response begins, the threshold is

37 °C for sweating & vasodilation,
36 °C for nonshivering thermogenesis, and

36.8 °C for vasoconstriction,
35.5 °C for shivering

Thermoreceptors



- Receptors that detect changes in temperature □ discharge to the hypothalamic control centers

Peripheral thermoreceptors

Site:- Skin, spinal cord, abdominal viscera and around great veins

- ❖ Monitor skin temperature
- ❖ warmth and cold receptors
- ❖ Concerned mainly with detection of cold

Central thermoreceptors

- Site:- Preoptic area of the anterior hypothalamus
- Monitor head (local) temperature
- Heat and cold sensitive

cells

Thermoregulatory mechanisms on exposure to heat



I- Mechanism decreasing heat production

- 1- Anorexia (loss of appetite)
- 2- Apathy and inertia
- 3- Inhibition of chemical thermogenesis:
 - Decrease thyroxine secretion

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II- Mechanism increasing heat loss

- 1- Cutaneous vasodilation
- 2- Sweating

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III- Voluntary control

via (reduced activity, using fan or air conditioner & wearing light, loose clothes) to reduce heat gain

Thermoregulatory mechanisms on exposure to cold



I- Mechanism increasing heat production

- 1- Increase muscle tone and shivering
- 2- Increase secretion of thermogenic hormones
- 3- Increase sense of hunger and appetite
- 4- Increased motor activity

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II- Mechanism decreasing heat loss

- 1- Cutaneous vasoconstriction
- 2- Piloerection
“?”
- 3- Curling up

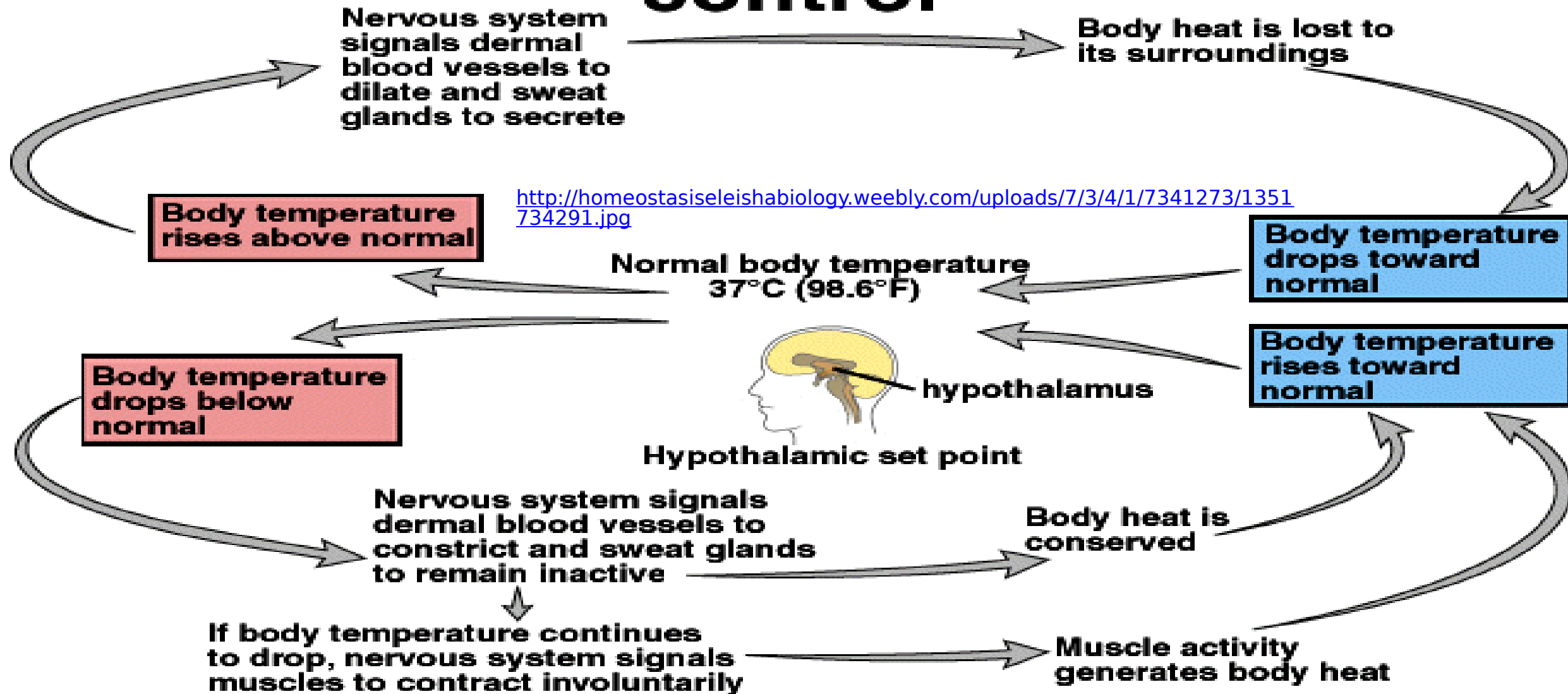
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III- Behavioral control

- ❖ Wearing several layers
- ❖ Voluntary ms. cont.
e.g. clasp the arms across the chest & exercise (clapping the hands)



Homeostasis and temperature control



Abnormal body temp.



Hyperthermia (heat stroke)

An elevation of body temperature higher than the thermoregulatory set point (usually above 41°C)

Sun stroke

A severe condition of heat stroke due to prolonged exposure to solar sun rays

Fever

Elevation of the core body temperature above the level which is normally maintained by the individual

Hypothermia

A core temperature less than 35°C

Frost bites

when the body is exposed to an extremely low temperature, the surface area can freeze, this freezing is called frostbite

Fever (Pyrexia)



It means elevation of the core body temperature above the level which is normally maintained by the individual

The thermoregulatory mechanisms behave as if they were adjusted to maintain body temperature at a higher than normal level

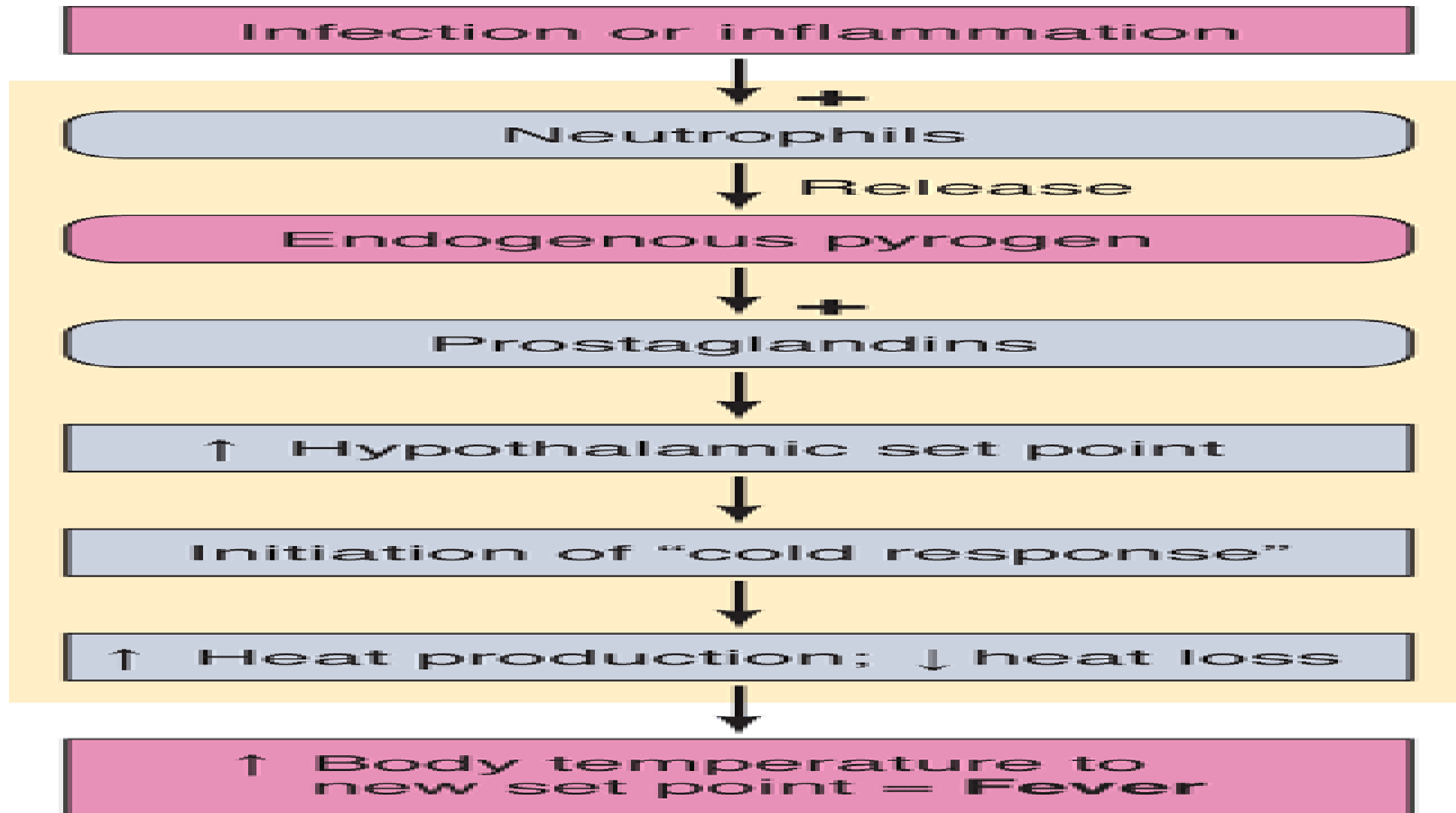
“as if the thermostat had been reset” to a new point above 37 °C”

So, all the mechanisms for raising the body temperature are activated **e.g. shivering, vasoconstriction,....**

Body temperature rarely exceeds 41 °C.

- It commonly results from bacterial infection
- It also results from certain brain lesions

Pathogenesis “Mechanism” of fever



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Pathogenesis “Mechanism” of fever



Pyrogens act on immune system cells (monocytes, macrophages and kupffer cells) → produce cytokines e.g. interleukin-6 (IL-6), Tumor necrosis factor (TNF- α), interleukin-1 (IL-1 β) & interferons (β -IFN, γ -IFN)

Cytokines are also produced by cells in the central nervous system (CNS) when these are stimulated by infection, and these may act directly on the thermoregulatory centers

These pyrogens activate preoptic areas through local release of prostaglandins

Substances (Drugs) which decrease fever are anti prostaglandins

Significance of fever



- ❖ Directly inhibits the growth of many microorganisms
- ❖ Interleukin-1 increases formation of neutrophils in the bone marrow → attack microorganisms & (+) Lymphocytes
→ increase production of antibodies → increases immunity
- ❖ Slows the growth of some tumors

N.B.: Temp. above 43 °C causes heat stroke & death due to permanent brain damage

Lecture Quiz



Q. 1 On exposure to a cold weather, one of the major means of increasing heat production is.....

- a) skin vasoconstriction
- b) wearing warm clothing
- c) increased muscle activity

Q. 2 If the surrounding temperature is greater than that of the skin, the only mechanism for heat loss will be.....

- a) Sweating
- b) Radiation
- c) Conduction
- D. convection.

Q. 3 the set point of body temperature regulation in feverished person is which of the following?

- b) Is the same of normal person
- b) elevated than in the normal person
- c) Lower than in the normal person

SUGGESTED TEXTBOOKS



1. Ganong's "Review of Medical Physiology", 25th edition, chapter 17, Section III, pages 319-320
2. Guyton and Hall "Textbook of Medical Physiology", 11th edition, chapter 72, pages 867-880
3. Sembulingam "Essentials of Medical Physiology", 6th edition, chapter 63, Section 5, pages 359-364 & Chapter 130, pages 746-748

